System Diagnostics and Troubleshooting Procedures

John Tomczyk

esco press

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Mount Prospect, Illinois

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CHAPTER ONE

Diagnosing Air Conditioning Systems

Air conditioning system diagnosis is not easy. A service technician must be a trained professional to diagnose a system efficiently and correctly, because it is no longer good practice to rely on rules of thumb for coil temperatures or pressures.

Air conditioning system problems mainly fall into two categories: air flow problems and refrigerant cycle problems. Both of these types of problems will be discussed in this chapter.

AIR FLOW

When there is an air side problem in an air conditioning system, it is usually because there is either too much air or too little air. Assuming that the entire air conditioning (a/c) unit was originally set up and operated properly, too much air probably will not be a problem area. This is because air handling systems do not just suddenly increase their air volume flow (cfm) without some outside help.

If the driven shieve on the blower motor becomes loose, the driven belt will ride lower on the driven shieve, decreasing fan speed instead of increasing it. It is also possible to rule out fan speed being too high, because most a/c units call for higher fan speeds to move the higher densities of colder air associated with air conditioning. This is why the majority of air flow problems involve not enough air flow rather than too much air flow. Remember, however, that air conditioning systems are not always set up properly in the first place. The duct system may not have been designed properly, resulting in oversized, undersized, or leaky ducts.

To determine if there is an air flow or refrigerant flow problem, first record the air temperatures into and out of the evaporator coil and determine if they are higher or lower than they should be. An air flow that is too low will give greater temperature differences across the coil than too much air flow. This greater temperature difference is from the air being in contact with the coil longer, thus decreasing its temperature coming out of the coil. By comparing the measured temperature difference to the manufacturer's required temperature differences, a technician can establish whether there is an air flow problem or a refrigerant flow problem.

To determine the required temperature difference across the coil, a technician must obtain the wb and db temperatures of the air entering the coil. A psychrometer, which was discussed in Chapter Five, is the only instrument needed for these measurements. In fact, a thermistor or thermocouple with a wet piece of cotton wrapped around it can give the wb temperature accurately enough for air conditioning work. Once the wb and db temperatures of the entering air are measured, the relative humidity of the entering air can be obtained from a chart or table (see Table 5-2 in Chapter Five). In Figure 6-1, for a constant air entering or return air db temperature, the temperature difference across the coil increases with decreasing relative humidities. The reason for this larger temperature difference with lower relative humidities is the decreased moisture (latent) load that the a/c coil has to condense. If the coil does not have to condense as much moisture out of the air, it can perform more sensible cooling because the coil temperature will be lower. Sensible cooling is exactly what is being measured when obtaining the temperature difference across a cooling coil with a db temperature.

If the temperature difference is greater than the required temperature difference across the coil, there is an air flow problem. The problem is not enough air flow, causing the air to stay in contact with the coil much too long and giving a greater temperature difference across the coil. If the temperature difference across the coil is less than the required temperature difference, the problem would be a refrigerant flow problem. This is because a/c systems hardly ever increase in air flow without some kind of human intervention. Some causes of decreased air flow in an a/c system include the following:

- Dirty air filters
- Faulty duct design
- Loose fan pulleys
- Slipping fan belts
- Blower motor running slow (burning out)

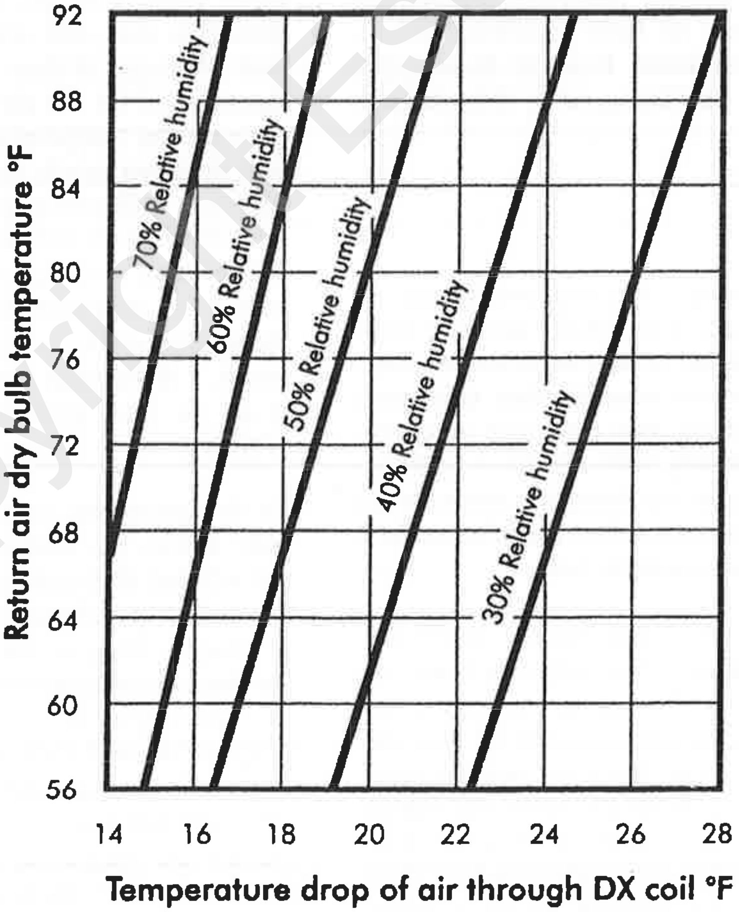

Figure 6-1. Temperature differences across a/c coils as a function of return air db temperature and relative humidity

- Restriction in duct system
- Dirty evaporator coil
- Dirty or missing fan blades
- Direct drive blower with wrong speed tap on the motor

REFRIGERANT CYCLE

As stated earlier, if there is a low temperature difference across the evaporator coil, the problem is refrigerant flow. The low temperature difference also indicates a capacity drop, meaning that the heat handling capabilities of the system have failed. Assuming the a/c system has been running for some time under these conditions, the service problem cannot be electrical.

The larger the coil surface area of the evaporator, the closer the coil temperature will be to the entering air temperature. This forces the coil temperature to a higher temperature, which means the a/c unit will run higher evaporating (suction) pressures and temperatures. With this increase in vapor pressure and coil temperature, the a/c unit will experience higher efficiencies from the higher pressure refrigerant gases entering the reciprocating compressor with each revolution of its crankshaft. The compression ratio will decrease from the higher evaporator temperatures and pressures, causing the mass flow rate of refrigerant vapors through the compressor to increase. These are the reasons why manufacturers produce larger, more efficient a/c coils. The larger and more efficient the coil, the smaller the coil temperature from the entering air temperature. This causes higher evaporator pressures and more efficient a/c units. This larger and more efficient coil does increase the manufacturing cost, but increased unit efficiency should offset the higher costs. The term used to describe an a/c unit's efficiency is the *Energy Efficiency Rating (EER).*

Remember that coil surface area may vary from one manufacturer to another. One manufacturer may choose large coil areas for high suction pressures and smaller compressors, while another may use smaller surface area coils, which cause lower suction pressures and use larger compressors. As long as the a/c unit meets the required Btu requirements and EERs, it is a trade-off. Coil surface area is often a function of geographic region. Large surface coils running higher suction pressures may not have low enough coil temperatures to remove enough moisture (latent heat). Their apparatus dew points will be too high to condense the right amount of moisture from the air passing through the coil, causing high humidity, mold, and human discomfort.

Condensers

Other than having different pressures and temperatures, the condenser and evaporator are very similar. Condensers are usually a bit larger than the evaporator in order to handle the evaporator load, suction line superheat heat gain, heat of compression, and motor heat loads of the compressor. Like the evaporator, the surface area of the condenser affects the design temperature difference between the condensing temperature and the ambient temperature. The larger the condenser, the more expensive it is to manufacture, but the EER will be much higher. Condensing temperatures and pressures vary with coil surface area size and EER, just like evaporator temperatures and pressures.

As stated in a previous chapter, subcooling is defined as the difference between the measured liquid temperature and the saturation temperature at a given pressure. Condenser subcooling can be measured at the condenser outlet with a thermometer or thermocouple and a pressure gauge. Simply subtract the condenser outlet temperature from the saturation temperature at the condenser outlet to obtain the amount of liquid subcooling in the condenser. The saturation pressure must be measured at the condenser outlet and converted to a temperature. Always take the pressure at the same point the temperature is taken to alleviate any pressure drop error through the condenser.

A forced air condenser should have from 6° to 10°F of liquid subcooling if charged properly. However, the amount of condenser subcooling depends on the static and friction line pressure losses in the liquid line and will vary from system to system. The 6° to 10°F of liquid subcooling is assuming no liquid amplification pump is pressurizing the liquid out of the condenser. Condenser subcooling can be an indicator of the refrigerant charge in the system. For receiverless systems, less refrigerant charge means less subcooling. The rated EER has little or no affect on condenser subcooling.

Another factor that affects condenser subcooling is the air entering the condenser. As the condenser air entering temperature increases, the liquid subcooling decreases. This is because higher condensing (head) pressures force more of the subcooled liquid through the metering device to the evaporator. As a result, evaporator superheat is less due to increased flow rate through its coil.

Liquid Line Restrictions

Liquid line restrictions may be caused by a number of factors, including the following:

- Restricted filter drier
- Restricted TXV screen
- Kinked liquid line
- Kinked or bent U bend on lower condenser coil
- Restricted solder joint in the liquid line
- Oil logged capillary tube

A restricted liquid line starves the evaporator of refrigerant, which causes low pressures in the evaporator. If the evaporator is starved of refrigerant, the compressor and condenser will also be starved, because the evaporator will not absorb much heat for the condenser to reject. Most of the refrigerant will be in the condenser, which will not necessarily cause high head pressures because of the reduced heat load on the evaporator. Because most of the refrigerant charge is in the condenser, liquid subcooling in the condenser will increase. This is very different from an undercharge of refrigerant, which results in low condenser subcooling. If the system has a receiver, most of the refrigerant will be in the receiver, causing lower than normal head pressures.

Symptoms of a restricted liquid line include the following:

- Local cool spot after a severe restriction from expansion of refrigerant at the local pressure drop.
- Low ampere draw at the compressor from reduced refrigerant flow.
- Bubbles in the sightglass if the restriction is before the sightglass. (Sightglasses are optional on some systems.)
- High superheats from a starved evaporator.
- Low to normal head pressures in a system with a receiver due to liquid backed up in the condenser, but no heat load for condenser to reject.

Suction Line Restrictions

The suction line is a much more sensitive refrigerant line than the liquid line, because vapor instead of liquid flows through it. A restricted suction line will cause low suction pressures and a starved compressor and condenser. A starved compressor will lead to low compressor amp draw because of its lightened load. The condensing pressure will also be low because of its light load. Since suction line restrictions starve compressors of refrigerant, the entire mass flow rate of refrigerant will decrease through the system, causing high superheats from inactive evaporators. Restricted and/or dirty suction filters are the major cause of suction line restrictions.

If there is a suction line restriction, liquid subcooling in the condenser will be normal to a bit high, because a lot of refrigerant will be in the condenser coil but will not be circulated very fast. The condenser subcooling may be normal to a bit high if there is a receiver in the system. Condenser subcooling lets the technician know there is refrigerant in the system and that an undercharge of refrigerant can be ruled out.

Undercharge

Undercharged systems mean less mass flow rate throughout the entire system. Low suction and discharge pressures with high superheat in the evaporator are all indications of an undercharge. Severely undercharged systems will run very low condenser subcooling, because there is no refrigerant to subcool. If the subcooling drops to zero, the hot gas in the condenser will start to leave the condenser with some liquid, and bubbles will form in the sightglass if the system is fortunate enough to have one. Compressor amp draw will be low because of the decreased refrigerant flow. Service technicians may be confused as to whether the problem is an undercharge of refrigerant or a liquid line restriction. Remember, a liquid line restriction will give the system a lot of subcooling in the condenser and an undercharge will not. Otherwise, symptoms are very similar.

Overcharge

A system with an overcharge of refrigerant will have higher than normal condensing temperatures because of liquid backing up in the condenser causing high subcooling and robbing the condenser of useful condensing area. The elevated head pressure will cause the volumetric efficiency of the compressor to decrease because of higher pressures of re-expanding volume vapors in the clearance pocket of the compressor. The amp draw of the compressor will increase from the higher head pressure, creating higher compression ratios, and the entire system will have reduced capacities. If the system has a TXV metering device, the TXV will still try to maintain its superheat and the evaporator pressure will be normal to slightly high, depending on the amount of overcharge. The higher evaporator pressure will be caused from the decreased mass flow rate from the higher compression ratio, and the evaporator will have a hard time keeping up with the higher heat load of the warm entering air temperature. The TXV will have a tendency to overfeed on its opening strokes due to the high head pressures.

If the system uses a capillary tube metering device, the same symptoms occur except for evaporator superheat. Remember, one reason a capillary tube system is critically charged is to prevent flooding of the compressor on low evaporator loads. The higher head pressures of an overcharged capillary tube system will have a tendency to overfeed the evaporator, resulting in decreased superheat. If the system is over 10% overcharged, liquid may enter the suction line and reach the suction valves or crankcase, resulting in compressor damage and failure.

Compressor Inefficiencies

Compressors are responsible for circulating refrigerant throughout a system; therefore, inefficient compressors will decrease the heat transfer ability of an air conditioning system. Leaky valves or worn piston rings are two of the major problems that lead to compressor inefficiencies. A symptom for an inefficient compressor is high suction pressure along with low discharge pressure. The evaporator will not be able to handle the load due to decreased refrigerant flow, and the conditioned space temperature will start to rise. This rise in return air temperature will overload the evaporator, causing high suction pressures and higher than normal superheats.

Piston ring blow-by and reed valve leakage can also cause high suction pressures. The condenser will see a reduced load from the decreased mass flow rate of refrigerant being circulated through it. The reduced condenser load will cause a low condensing pressure. The compressor amp draw will be lowered because of a lower work load from the low mass flow rate of refrigerant. Subcooling in the condenser should be a bit low from the reduced heat load on the condenser.

Symptoms of an inefficient compressor include the following:

- High suction pressures
- Low head pressures
- Low compressor amp draw
- High superheat
- High return air temperature
- Condenser subcooling (low to normal)

Noncondensibles

Air and water vapor are probably the best known noncondensibles in a refrigeration or air conditioning system. Noncondensibles usually enter a system through poor service practices and/or leaks. A technician forgetting to purge hoses can let air and water vapor into a system. The air and water vapor will pass through the evaporator and compressor because the compressor is a vapor pump. Once the air reaches the condenser, it will remain at its top and not condense. The subcooled liquid seal at the condenser bottom will prevent the air from passing out of the condenser. This air and water vapor will take up valuable condenser surface area and cause high head pressures. Subcooling will be high because the high head pressures cause a greater temperature difference between the liquid temperature in the condenser and the ambient. This will allow for more subcooling because of the greater temperature difference. Noncondensibles in a system and an overcharge of refrigerant have very similar symptoms when a TXV metering device is used. Often, the only way to distinguish between noncondensibles in a system and an overcharge is to shut the unit off for a while and let the condenser fan run. This will cool the system down quickly. Once the system is cooled down, if the pressures on the high side of the system still remain relatively high while the unit is off, noncondensibles are in the system. There will be no pressure/temperature relationship with the refrigerant and the ambient if noncondensibles are in the condenser. With an overcharge of refrigerant, the high side pressure should decrease rapidly with the system off and the condenser fan running.

Symptoms of noncondensibles in the system include the following:

- High head (condensing) pressures
- High subcooling
- High compression ratios
- High discharge temperatures

Low Condenser Air Entering Temperature

Low condenser air entering temperature will cause a low head pressure from the excessive heat transfer between this cool ambient and the condenser coil. Low head pressures may reduce flow through metering devices, which have capacity ratings dependent on the pressure differences across them. A 30 psi pressure difference is usually the minimum across TXVs. This reduced refrigerant flow causes a starved evaporator, which will cause low suction pressures and high superheats. However, this may be offset by increased subcooling at lower ambients.

This entire drop in capacity may decrease the heat removal ability of an air conditioner if it is not designed for it. If not designed properly, liquid will start to back up in the condenser. Because of a low heat transfer rate caused from the lower condenser temperature, the liquid temperature in the bottom of the condenser will be low, causing liquid subcooling in the condenser to increase. Less refrigerant circulated also means less work for the entire system, so the ampere draw of the compressor will be lowered.

If the system is set up for reduced condenser air entering temperature, the head pressure can be designed to float or change with the changing ambient temperature. This will give lower head pressures and increased efficiencies. A properly matched TXV to handle reduced pressure drops across its orifice may have to be incorporated into the design (see Chapter Two). Symptoms of reduced condenser air entering temperature include the following:

- Low entering air temperature
- Low suction pressure (if not designed for low head pressure at TXV)
- Low discharge (condensing) pressure
- High superheat (if not designed for low head pressure at TXV)
- Low amp draw
- High subcooling

High Condenser Air Entering Temperature

Higher outdoor ambients will cause head pressures to elevate in order to complete the heat rejection task. The temperature difference (TD) between condensing temperature and ambient will go down, and the refrigerant gas will not condense until the head pressure rises. The condenser cannot reject as much heat at this lower TD and will accumulate the heat. The accumulated heat forces the condensing temperature to elevate to a TD where the heat can be rejected. Remember, the temperature difference is the driving potential for heat transfer. However, this heat rejection happens at a higher condensing temperature, forcing the system to have higher compression ratios and lower efficiencies.

High head pressures cause the compression ratio to increase, causing low volumetric efficiencies from higher pressure vapors re-expanding in the clearance volume of the piston cylinder on each downstroke. As volumetric efficiencies decrease, mass flow rates decrease and the compressor is less efficient. High head pressures will also elevate liquid temperatures entering the metering device, which will increase evaporator flash gas and decrease the net refrigeration effect. Because of these inefficiencies, the suction pressure may be a bit higher. The system will have a hard time maintaining temperature and humidity of the conditioned space. Evaporator superheat will vary depending on the type of metering device.

Capillary Tubes

Flow rates through a capillary tube metering device or any fixed orifice metering device depend on the pressure difference across the metering device. Higher head pressures will increase the flow rate through the metering device, pushing the subcooled liquid at the condenser bottom through the metering device at a faster rate. Because of this, condenser subcooling will decrease. Evaporator superheat will also decrease because of a flooded evaporator coil with a lot of flash gas at its entrance.

TXVs

TXV systems will try to maintain evaporator superheat even though the pressure drop across the valve may be out of its control range at the higher ambient temperatures. Here, the condenser subcooling may be normal to a bit high.